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STATIC-THRUST INVESTIGATION OF FULL-SCALE PV-2 HELICOPTER ROTORS HAVING NACA 0012.6 AND 23012.6 AIRFOIL SECTIONS

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NACA LANGLEY MEMORIAL AERONAUTICAL LABORATORY

MEMORANDUM REPORT

for the

Bureau of Aeronautics, Navy Department

MR No. L6D24

STATIC-THRUST INVESTIGATION OF FULL-SCALE PV-2 HELICOPTER ROTORS HAVING NACA 0012.6 AND 23012.6 AIRFOIL SECTIONS

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SUMMARY

An investigation to compare the performance of two 25-foot-diameter rotors constructed by the P-V Engineering Forum has been conducted at the Langley full-scale tunnel. The rotors, which were designed to operate on the PV-2 helicopter, had identical dimensions and were similar in construction but differed in blade airfoil section - one having an NACA 0012.6 airfoil section and the other, an NACA 23012.6 airfoil section. The tests were conducted at three different rotational speeds including the design rotor speed of 371 rpm.

The results of the tests are presented as the variation of torque coefficient with thrust coefficient. A comparison of the results obtained with the 0012.6 rotor from the present tests and from a previous investigation shows excellent agreement. Only small differences were apparent between the performance characteristics of these symmetrical- and cambered-section blades although at the higher thrust coefficients the performance of the cambered blades became increasingly better. The comparison of their performance is probably impaired by the poorer surface condition of the cambered rotor. The performance of both rotors could be substantially improved, as indicated by previous full-scale-tunnel tests, by the elimination of certain surface irregularities. The test

results also showed that the effect of a discus which was 84 inches in diameter (28 percent of the rotor diameter) was negligible in the range of normal hovering flight conditions.

INTRODUCTION

At the request of the Bureau of Aeronautics, Navy Department, tests were made at the Langley full-scale tunnel to compare the performance of two 25-foot-diameter rotors constructed by the P-V Engineering Forum. The rotors, which were designed to operate on the PV-2 helicopter, were similar in construction but differed in their blade airfoil section, one having an NACA 0012.6 section and the other using an NACA 23012.6 section. Previous static-thrust and forward-flight performance tests were made at reduced rotor speeds on the rotor having the symmetrical section and are reported in reference 1. The present report presents static-thrust data obtained for the two rotors at three rotational speeds, including the design rotor speed of 371 rpm. The effect on the rotor characteristics of adding a discus with a diameter of 84 inches, which is 28 percent of the rotor diameter, was also investigated.

SYMBOLS

C_T thrust coefficient, $T/\rho(\Omega R)^2\pi R^2$

C_Q torque coefficient, $Q/\rho(\Omega R)^2\pi R^2 R$

R rotor radius, feet

T rotor thrust, pounds

Q rotor torque, foot-pounds

Ω angular velocity of rotor, radians per second

ρ mass density of air, slugs per cubic foot

σ solidity, $bc/\pi R$

b number of rotor blades

c blade chord at $\frac{3}{4}R$, feet

APPARATUS AND TESTS

The rotors tested in this investigation were designed to operate at 371 rpm on a helicopter having a gross weight of 1000 pounds. The test rotors had a diameter of 25 feet, a solidity of 0.0605, and were three-bladed. They are referred to by their airfoil sections which were NACA 0012.6 and 23012.6, respectively. Other details of the dimensions and the construction (figs. 1 and 2) were identical except as noted in the following description. Each blade consists of a tubular steel spar to which wooden ribs are attached and covered with fabric which is reinforced over approximately the forward third of the blade chord by a layer of 3/64-inch plywood glued to the ribs. Similar reinforcing is used at the extreme tip of the blades with the symmetrical section and for the width of the entire chord over the outer 20 percent of the 23012.6 blades. The surface of the 0012.6 rotor blades has some flat spots at the tip and some departures from a smooth airfoil contour near the leading edge and just aft of the thin plywood reinforcing. These latter deviations from an accurate contour are especially noticeable on the 23012.6 rotor blades in which there is approximately a 1/64-inch jog in the airfoil contour on the upper and lower surfaces of all three blades at approximately 0.04c and just rearward of the spruce leading-edge fairing strip.

Details of the discus used in the tests are shown in figures 1 and 3. It consisted of a fabric-covered framework of thin-wall metal tubes and had a diameter of 84 inches, which is 28 percent of the rotor diameter.

The general arrangement of the rotor mounted in the full-scale tunnel is shown in figure 4. The rotor was driven by an electric motor and the power input to the rotor was measured by a strain-gage torquemeter and by a pneumatic torquemeter. The rotor thrust, the rolling moment, and the pitching moments were measured by an auxiliary strain-gage balance. Force records were also obtained from the conventional wind-tunnel balances. A more complete description of the testing arrangement and instrumentation is given in reference 1.

Following the tests of reference 1, the pylon was stiffened sufficiently to enable the present series of tests to be made at the rotor design speed of 371 rpm without serious vibrations. The static-thrust tests were made with the rotor shaft vertical over a range of indicated blade pitch angles from 3° to 11.5° for rotor speeds of 200; 290, and 371 rpm. The rotor was kept trimmed in roll and pitch.

RESULTS AND DISCUSSION

The static-thrust results obtained for the 0012.6 rotor are presented in figure 5(a) in terms of the variation of the thrust coefficient with the torque coefficient. Similar results for the 23012.6 rotor alone and in combination with the 84-inch discus are given in figures 5(b) and 5(c). While theoretical considerations might indicate some scale effect, these results, like previous rotor tests made in the full-scale tunnel (see references 1 and 2), show no consistent effect on curves of thrust coefficient against torque coefficient due to changes in rotational speed. Only one curve, therefore, was faired through the data in each of these figures. The faired static-thrust curve for the 0012.6 rotor given in reference 1 has been included in figure 5(a) for the purpose of comparison with the more recent results. The two sets of data are in excellent agreement.

The results of the static-thrust tests are summarized in figure 6. The performance of the 23012.6 rotor becomes increasingly better than that of the 0012.6 rotor for thrust coefficients greater than about 0.0030. The flight conditions for the PV-2 helicopter corresponds to operation at a rotor tip speed of 485 feet per second and a rotor thrust coefficient of 0.00364. At this design thrust coefficient the difference in horsepower required to hover with each rotor is less than 2 percent. It appears probable that a somewhat larger difference might have been shown were it not for the slightly better surface condition of the symmetrical-section rotor. Also, since the cambered section shows increasing gains at thrust coefficients beyond the design value up to the highest value covered by the data, the maximum gains obtainable would presumably be realized at still higher thrust coefficients. Theory indicates that the maximum effect of the blade camber would be realized just prior to the stall; however, power limitations on the electric drive motor prevented obtaining data nearer the blade stall.

The imperfect surface conditions of the two rotors tested undoubtedly impairs their static-thrust performance. The data of reference 2 indicate that elimination of surface deformation and irregularities may result in an average power saving in horsepower of as much as 10 percent. The close rib spacing and doped finish of the two rotors tested should prevent excessive drag losses due to surface deformation. The elimination of the rotor blade surface irregularities, however, should appreciably increase the performance of these rotors.

Figure 6 also shows that the 84-inch-diameter discus has no effect on the static-thrust performance throughout the normal operating range of the rotor although it produces a slight detrimental effect at the lower thrust coefficients.

CONCLUDING REMARKS

Static-thrust tests of two PV-2 helicopter rotors in the Langley full-scale tunnel show the following results:

1. At the design thrust coefficient of 0.00364, the 23012.6 rotor requires approximately 2 percent less power to hover than the symmetrical blades. This difference would probably be increased if the surface of the cambered blades was as relatively smooth as that of the symmetrical blades. At thrust coefficients above the design value the performance of the 23012.6 rotor becomes increasingly better than that of the 0012.6 rotor.

2. As indicated by previous full-scale-tunnel tests, improved performance of both rotors can probably be obtained by eliminating their surface discontinuities.

3. The use of an 84-inch-diameter discus had no appreciable effect on the static-thrust performance throughout the normal operating range of the rotor.

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REFERENCES

1. Migotsky, Eugene: Full-Scale-Tunnel Performance Tests of the PV-2 Helicopter Rotor. NACA MR No. L5C29a, 1945.

2. Dingeldein, Richard C., and Schaefer, Raymond F.: Static-Thrust Tests of Six Rotor-Blade Designs on a Helicopter in the Langley Full-Scale Tunnel. NACA ARR No. L5F25b, 1945.

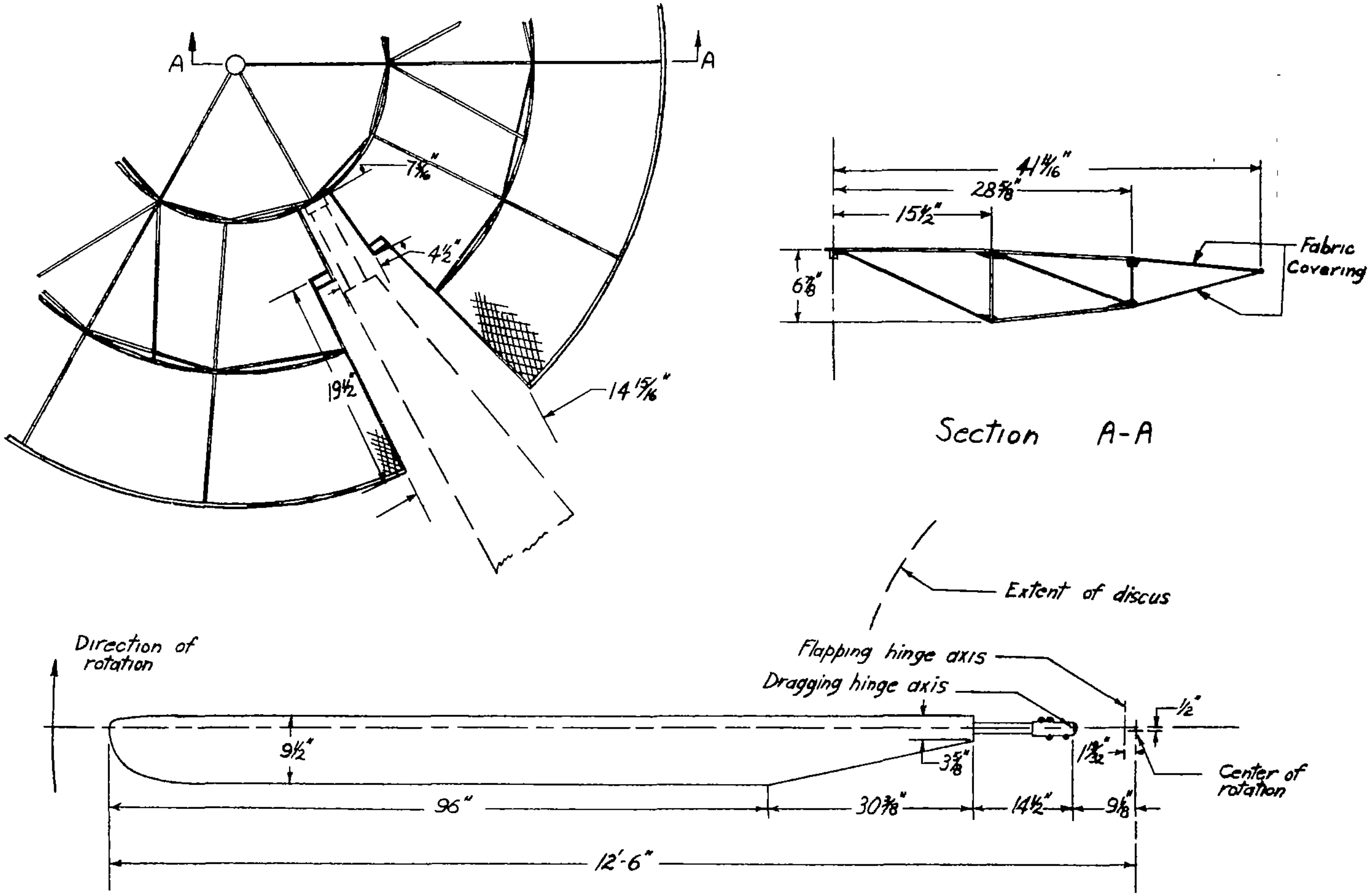

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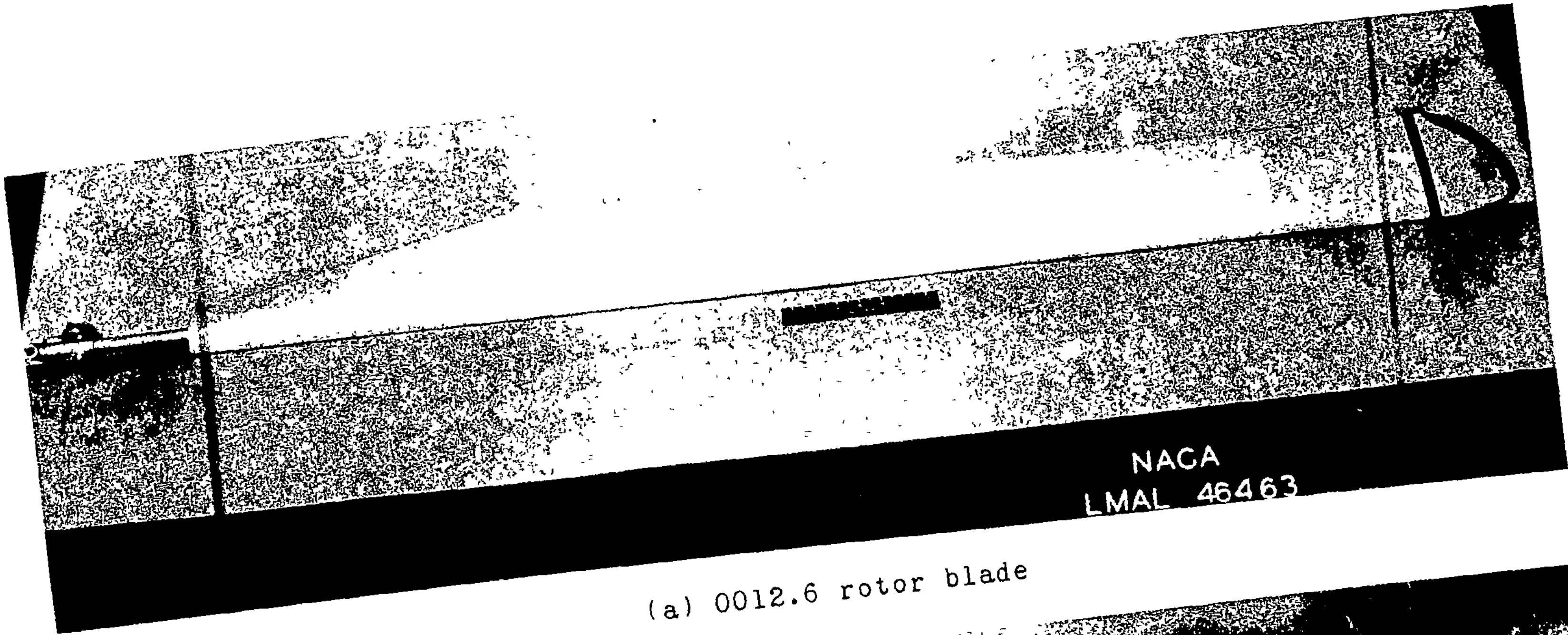
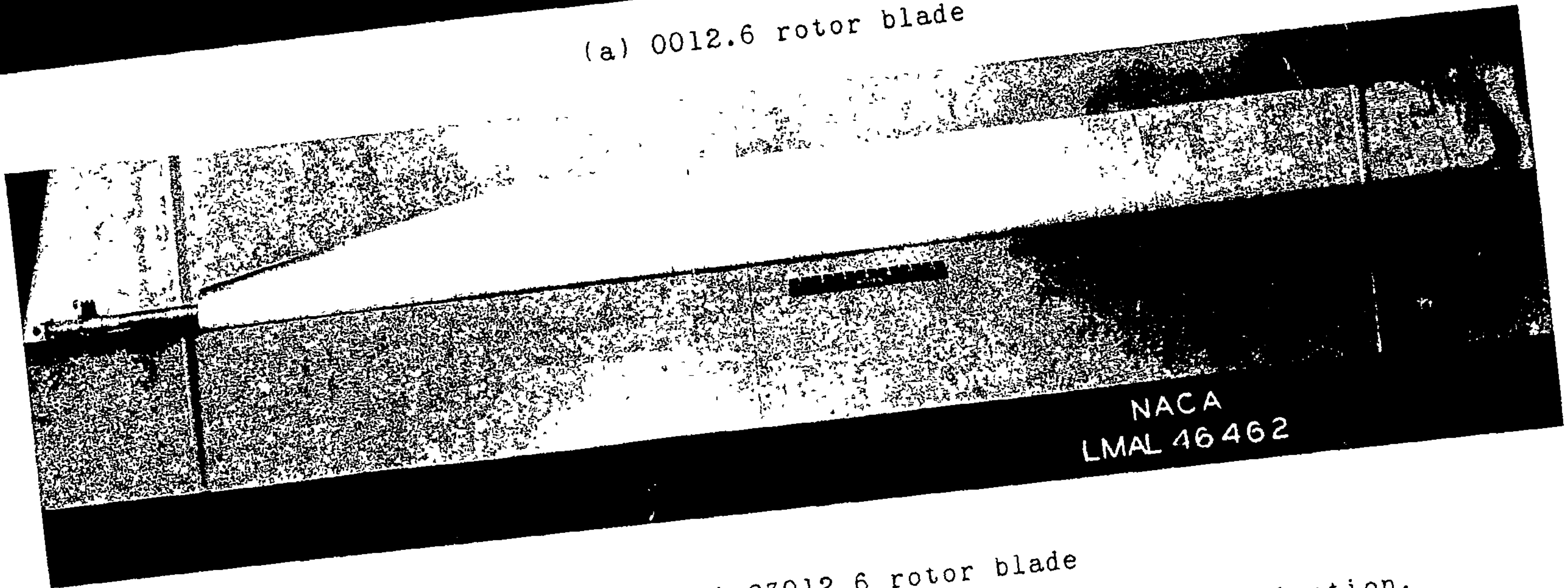
Figure 1.- Dimensions of a PV-2 helicopter rotor blade and the discus.

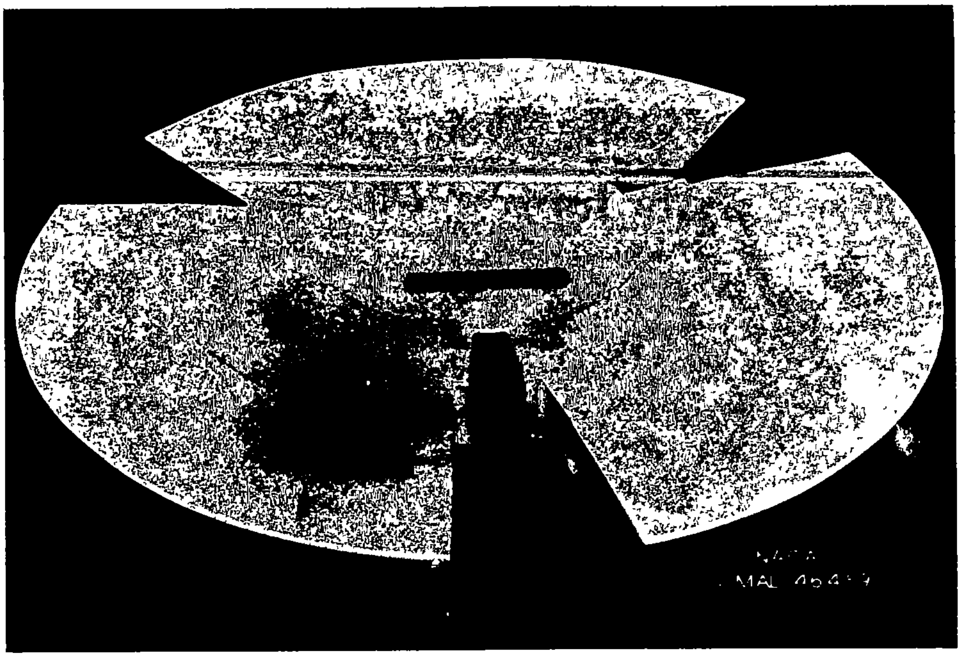


(a) 0012.6 rotor blade

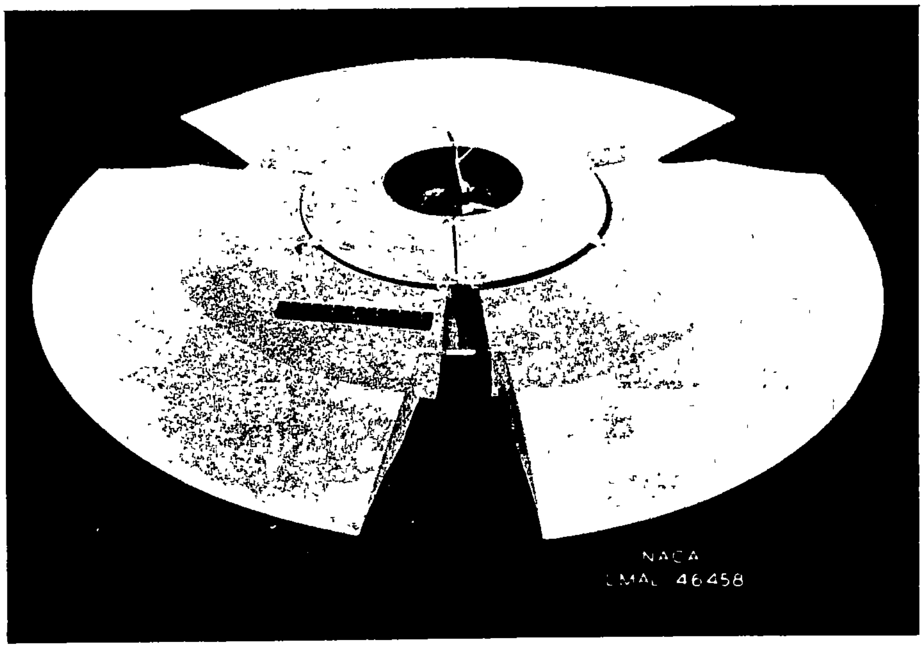


(b) 23012.6 rotor blade

tic-thrust investigation.



(a) Top view



(b) Bottom view

Figure 3.- 84-inch discus tested during static-thrust investigation.

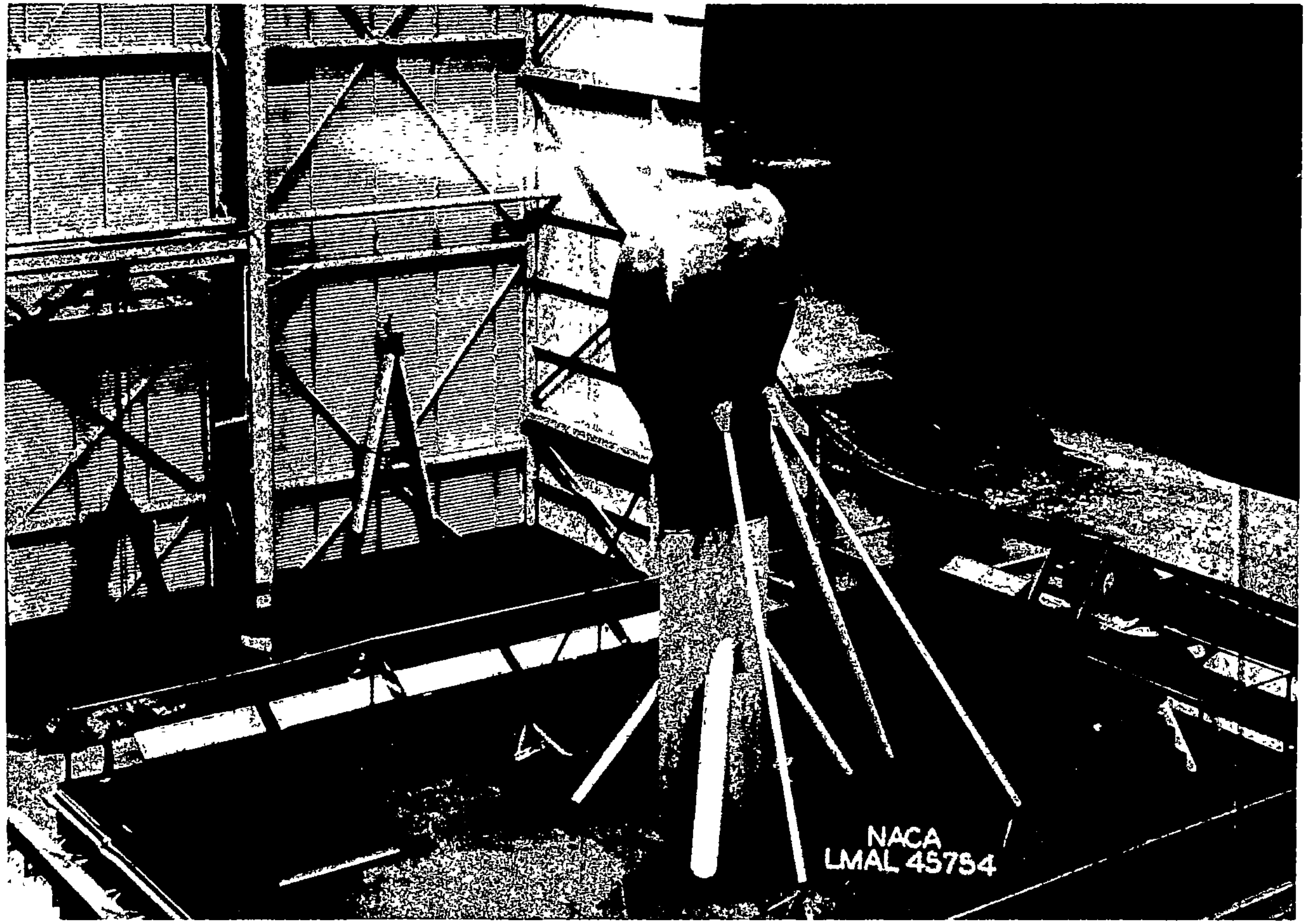
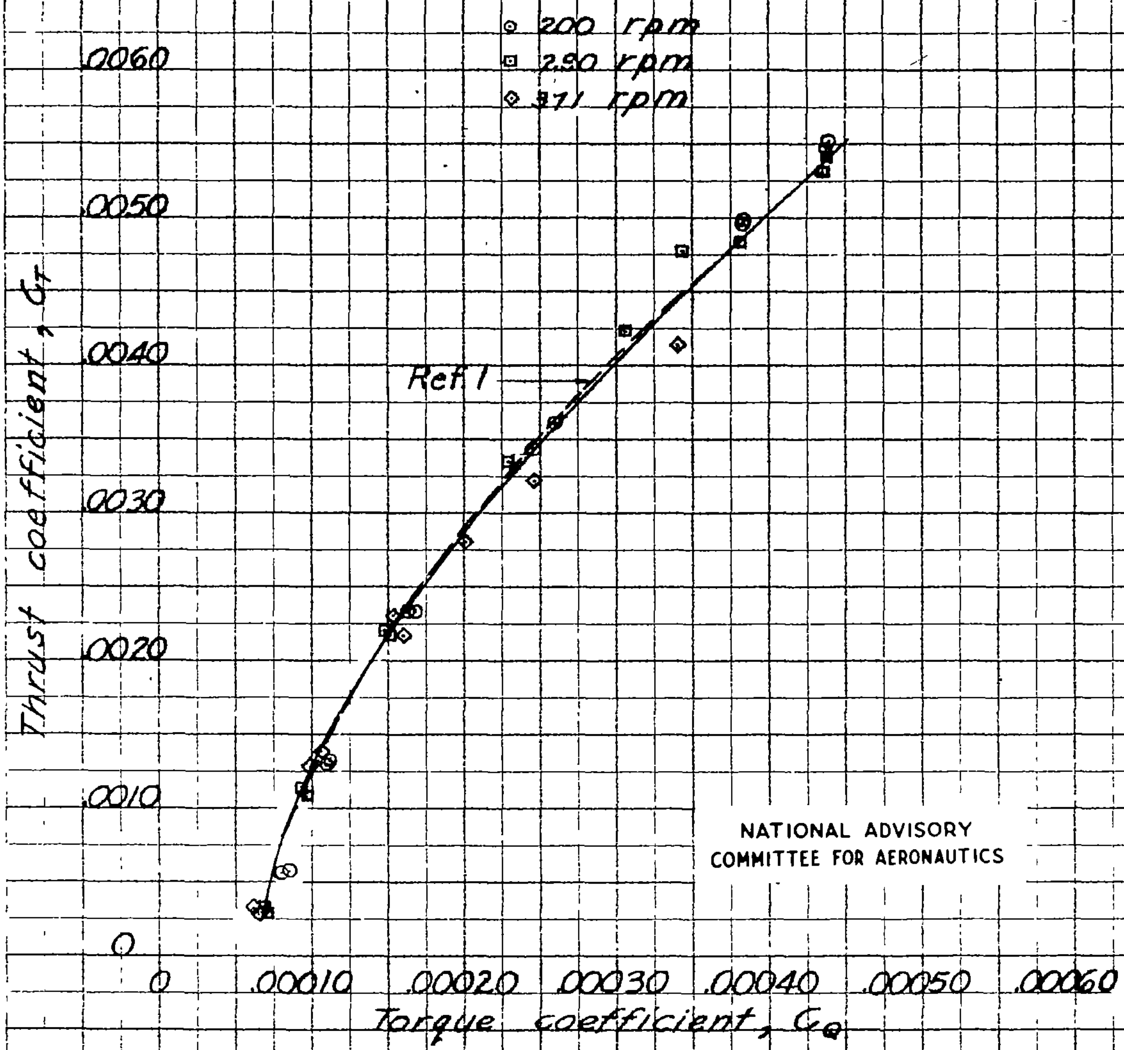
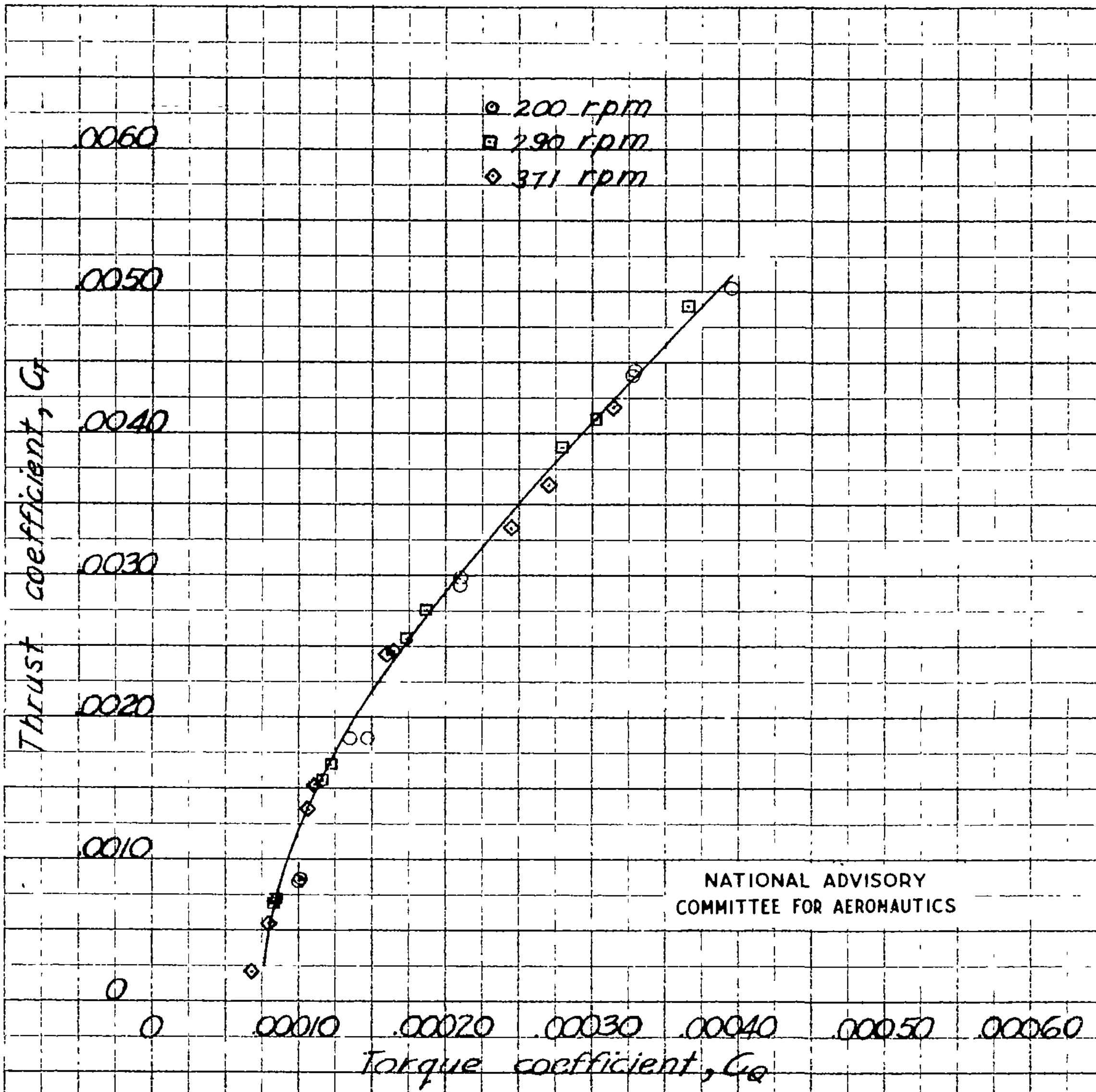


Figure 4.- General arrangement of the PV-2 helicopter rotor as tested in the Langley full-scale tunnel.



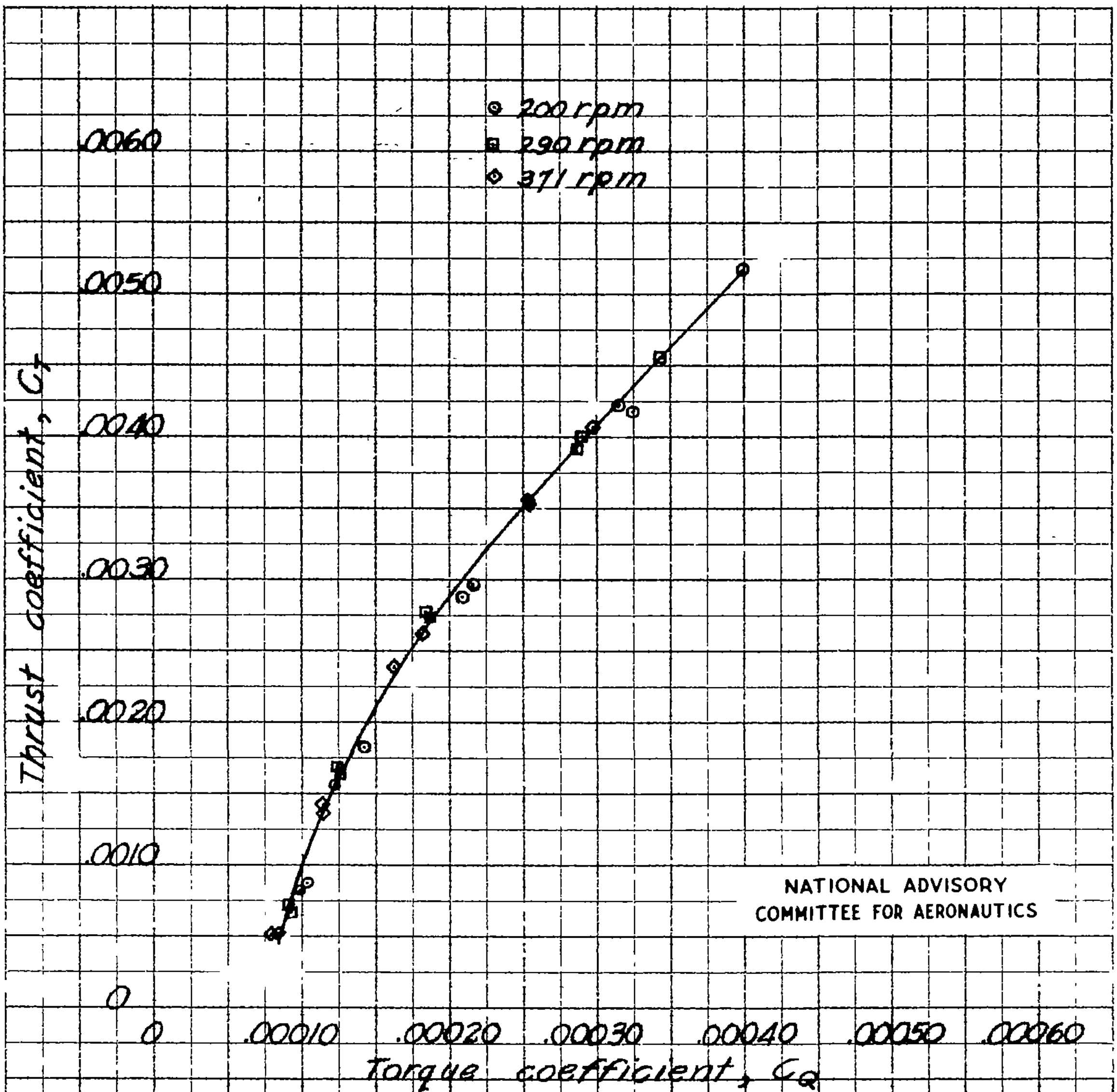
(a) 0012.6 rotor

Figure 5.- Static-thrust performance of the PV-2 helicopter rotors.



(b) 23012.6 rotor

Figure 5.- Continued.



(c) 23012.6 rotor with 84-inch discus

Figure 5.- Concluded.

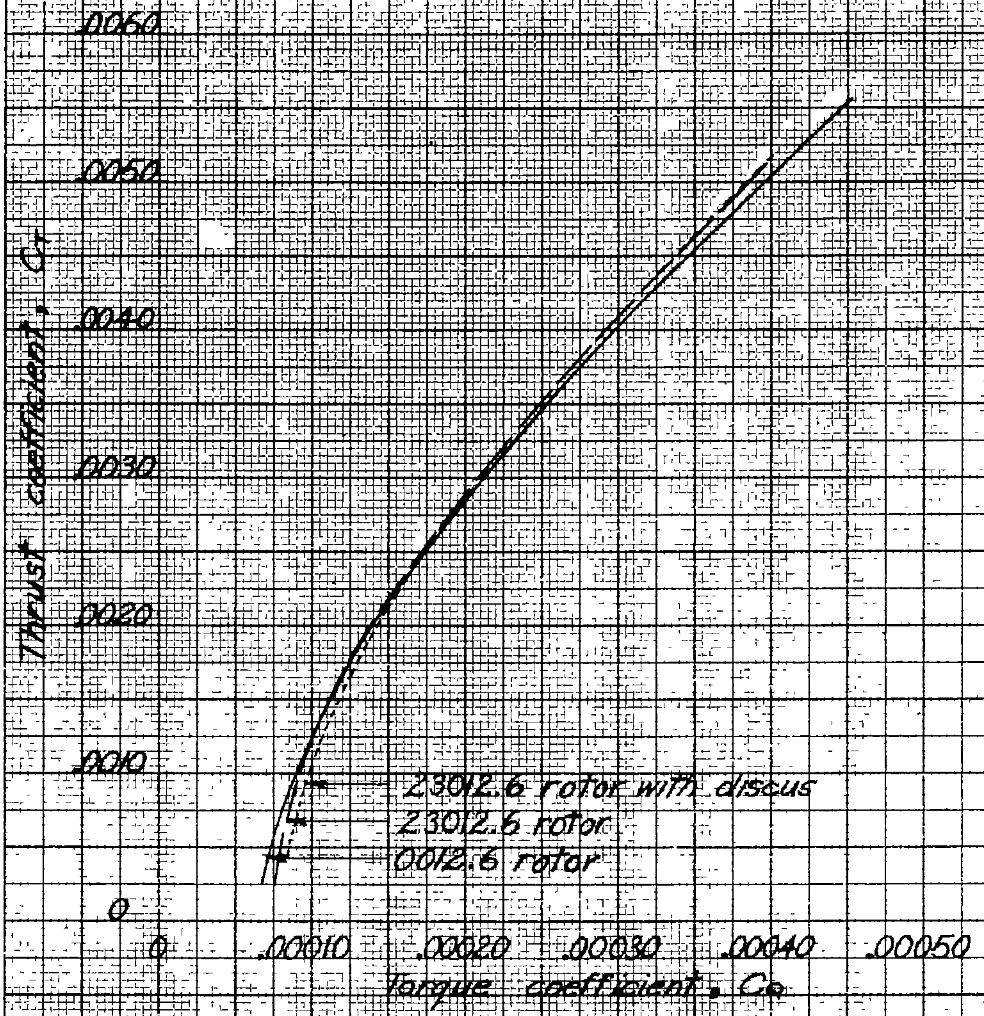


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Figure 6.- Summary of static-thrust performance of PV-2 helicopter rotors.